**MARKED UP VERSION OF SUBSTITUTE SPECIFICATION**

[Abstract] ABSTRACT OF THE DISCLOSURE

[ The invention relates to a]A method and a device for determining a variable describing the speed [$(V_{wheelDef})$of ]at least one driven wheel[ (1, 2, 3, 4)] of a motor vehicle. In this context, variables describing the respective wheel speeds [$(V_{wheeli})$]for the remaining driven wheels of the motor vehicle, and a variable describing the output rpm [$(n_{output})$ ]of a transmission[ (5)] of the motor vehicle are determined. To be able to make a reliable variable describing the speed magnitude of the wheel[ (1, 2, 3, 4)] available to a traction control system or a vehicle-dynamics control system of a motor vehicle in spite of the failure of a speed sensor [(9, 10, 11, 12) ]arranged at one of the wheels,[ it is proposed that] the variable describing the speed [$(V_{wheelDef})$ ]for the at least one driven wheel [(1, 2, 3, 4) be]is determined as a function of the variables [which describe]describing the respective wheel speeds [$(V_{wheeli})$ ]of the remaining driven wheels and as a function of the variable [which describes]describing the transmission output rpm[ $(n_{output})$.].

[(Figure 1)]

398890

JC20 Rec'd PCT/PTO 08 AUG 2001

| FORM PTO-1390 (REV. 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE | ATTORNEY'S DOCKET NUMBER 10191/1961 |
|---|---|
| **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371** | U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/913005 |

| INTERNATIONAL APPLICATION NO. | INTERNATIONAL FILING DATE | PRIORITY DATE(S) CLAIMED |
|---|---|---|
| PCT/EP00/12365 | (08.12.00)<br>08 December 2000 | (08.12.99)<br>08 December 1999 |

TITLE OF INVENTION
**METHOD AND DEVICE FOR DETERMINING A SPEED VARIABLE OF AT LEAST ONE DRIVEN WHEEL OF A MOTOR VEHICLE**

APPLICANT(S) FOR DO/EO/US

**Andreas ERBAN**

Applicant(s) herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☒ has been transmitted by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☐ have been transmitted by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

**Items 11. to 16. below concern other document(s) or information included:**

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ A substitute specification and a marked up version thereof.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report and Form PCT/RO/101.

Express Mail No. EL244507281US

518 Rec'd PCT/PTO 08 AUG 2001

| U.S. APPLICATION NO. if known, see 37 C.F.R.1.5 09/913005 | INTERNATIONAL APPLICATION NO. PCT/EP00/12365 | ATTORNEY'S DOCKET NUMBER 10191/1961 |
|---|---|---|

17. ☒ The following fees are submitted:

| | CALCULATIONS | PTO USE ONLY |
|---|---|---|
| **Basic National Fee (37 CFR 1.492(a)(1)-(5)):**<br>Search Report has been prepared by the EPO or JPO .................... $860.00<br><br>International preliminary examination fee paid to USPTO (37 CFR 1.482) .... $690.00<br><br>No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .............. $710.00<br><br>Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO ...................... $1,000.00<br><br>International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) ...................... $100.00 | | |
| **ENTER APPROPRIATE BASIC FEE AMOUNT =** | $ 860 | |
| Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)). | $ | |

| Claims | Number Filed | Number Extra | Rate | | |
|---|---|---|---|---|---|
| Total Claims | 26 - 20 = | 6 | X $18.00 | $ 108 | |
| Independent Claims | 5 - 3 = | 2 | X $80.00 | $ 160 | |
| Multiple dependent claim(s) (if applicable) | | | + $270.00 | $ 0 | |

| | | |
|---|---|---|
| **TOTAL OF ABOVE CALCULATIONS =** | $ 1,128 | |
| Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1 28). | $ | |
| **SUBTOTAL =** | $ 1,128 | |
| Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). + | $ | |
| **TOTAL NATIONAL FEE =** | $ 1,128 | |
| Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property + | $ | |
| **TOTAL FEES ENCLOSED =** | $ 1,128 | |
| | Amount to be: refunded | $ |
| | charged | $ |

a. ☐ A check in the amount of $__________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. ~~11-0600~~ in the amount of $1,128.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Richard Mayer (By AC Reg. No. 33,865 Aaron C Deditch)

SIGNATURE

Kenyon & Kenyon
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Richard L. Mayer, Reg. No. 22,490
NAME

8/8/2001
DATE

395833

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[10191/1961]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | | |
|---|---|---|
| Applicant(s) | : | Andreas ERBAN |
| Serial No. | : | To Be Assigned |
| Filed | : | Herewith |
| For | : | METHOD AND DEVICE FOR DETERMINING A SPEED VARIABLE OF AT LEAST ONE DRIVEN WHEEL OF A MOTOR VEHICLE |
| Art Unit | : | To Be Assigned |
| Examiner | : | To Be Assigned |

Assistant Commissioner
for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

SIR:

Please amend without prejudice the above-identified application before examination, as set forth below.

**IN THE TITLE:**

Please amend without prejudice the title to be:
--METHOD AND DEVICE FOR DETERMINING A SPEED VARIABLE OF AT LEAST ONE DRIVEN WHEEL OF A MOTOR VEHICLE--.

**IN THE SPECIFICATION AND ABSTRACT:**

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

**IN THE CLAIMS:**

Without prejudice, please cancel original claims 1 to 12, and please add new claims 13 to 38 as follows:

EL244507281US

--13. (New) A method for determining a speed variable describing a speed of at least one driven wheel of a motor vehicle, the method comprising:

determining variables describing respective wheel speeds of remaining driven wheels of the motor vehicle;

determining an output rpm variable describing a transmission output rpm of a transmission of the motor vehicle; and

determining the speed variable describing the speed of the at least one driven wheel as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output rpm variable describing the transmission output rpm.

14. (New) The method of claim 13, further comprising:

determining an output speed variable specific to a wheel plane and describing an output speed as a function of the transmission output rpm;

wherein the speed variable describing the speed of the at least one driven wheel is determined as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output speed variable describing the output speed.

15. (New) The method of claim 14, wherein the output speed variable specific to the wheel plane and describing the output speed is determined according to the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} ,$$

where $R_{wheel}$ is a radius of the driven wheels and $I_{Diff}$ is at least one effective differential ratio.

16. (New) The method of claim 14, wherein the motor vehicle has all-wheel drive, and the speed variable describing the speed of the at least one driven wheel is determined according to the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} .$$

17. (New) The method of claim 14, wherein the motor vehicle has one of front-wheel drive and rear-wheel drive, and the speed variable describing the speed for the at least one driven wheel is determined according to the equation of:

$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$, where $V_{wheel}$ is a wheel speed of another driven wheel.

18. (New) A device for determining a speed variable describing a speed of at least one driven wheel of a motor vehicle, the device comprising:

a first arrangement for determining variables describing respective wheel speeds of remaining driven wheels of the motor vehicle;

a second arrangement for determining an output rpm variable describing a transmission output rpm of a transmission of the motor vehicle; and

a third arrangement for determining the speed variable describing the speed for the at least one driven wheel as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output rpm variable describing the transmission output rpm.

19. (New) The device of claim 18, wherein:

the device includes an arrangement for determining an output speed variable specific to a wheel plane and describing an output speed as a function of the transmission output rpm; and

the speed variable describing the speed of the at least one driven wheel is determined as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output speed variable describing the output speed.

20. (New) The device of claim 19, wherein the output speed variable specific to the wheel plane and describing the output speed is determined according to the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} ,$$

where $R_{wheel}$ is a radius of the driven wheels and $I_{Diff}$ is at least one effective differential ratio.

21. (New) The device of claim 19, wherein the motor vehicle has all-wheel drive, and the speed variable describing the speed of the at least one driven wheel is determined according to the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} \ .$$

22. (New) The device of claim 19, wherein the motor vehicle has one of front-wheel drive and rear-wheel drive, and the speed variable describing the speed for the at least one driven wheel is determined according to the equation of:

$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$, where $V_{wheel}$ is a wheel speed of another driven wheel.

23. (New) A control unit for one of a traction control system and a vehicle-dynamics control system of a motor vehicle for controlling at least one of drive slip and vehicle dynamics, the control unit comprising:

an arrangement for determining a speed variable describing the speed of at least one driven wheel of the motor vehicle, wherein variables describing respective wheel speeds of remaining driven wheels of the motor vehicle and an output rpm variable describing a tranmsission output rpm of a transmission of the motor vehicle are available to the control unit;

wherein the control unit determines the speed variable describing the speed for the at least one driven wheel as a function of the variables describing the respective wheel speeds of the remaining driven wheels and as a function of the output rpm variable describing the transmission output rpm.

24. (New) The control unit of claim 23, wherein:

the control unit includes an arrangement for determining an output speed variable specific to a wheel plane and describing an output speed as a function of the transmission output rpm; and

the speed variable describing the speed of the at least one driven wheel is determined as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output speed variable describing the output speed.

25. (New) The control unit of claim 24, wherein the output speed variable specific to the wheel plane and describing the output speed is determined according to the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} ,$$

where $R_{wheel}$ is a radius of the driven wheels and $I_{Diff}$ is at least one effective differential ratio.

26. (New) The control unit of claim 24, wherein the motor vehicle has all-wheel drive, and the speed variable describing the speed of the at least one driven wheel is determined according to the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} .$$

27. (New) The control unit of claim 24, wherein the motor vehicle has one of front-wheel drive and rear-wheel drive, and the speed variable describing the speed for the at least one driven wheel is determined according to the equation of:

$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$ , where $V_{wheel}$ is a wheel speed of another driven wheel.

28. (New) A memory element comprising:

at least one of a read-only memory, a random-access memory and a flash memory for use in a control unit of one of a traction control system and a vehicle-dynamics control system of a motor vehicle;

wherein the memory element stores a computer program that is executable on at least one of a computing element and a microprocessor for performing a process for determining a speed variable describing a speed of at least one driven wheel of a motor vehicle, the process including:

determining variables describing respective wheel speeds of remaining driven wheels of the motor vehicle;

determining an output rpm variable describing a transmission output rpm of a transmission of the motor vehicle; and

determining the speed variable describing the speed of the at least one driven wheel as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output rpm variable describing the transmission output rpm.

29. (New) The memory element of claim 28, wherein:

the process includes determining an output speed variable specific to a wheel plane and describing an output speed as a function of the transmission output rpm; and

the speed variable describing the speed of the at least one driven wheel is determined as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output speed variable describing the output speed.

30. (New) The memory element of claim 29, wherein the output speed variable specific to the wheel plane and describing the output speed is determined according to the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} ,$$

where $R_{wheel}$ is a radius of the driven wheels and $I_{Diff}$ is at least one effective differential ratio.

31. (New) The memory element of claim 29, wherein the motor vehicle has all-wheel drive, and the speed variable describing the speed of the at least one driven wheel is determined according to the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} .$$

32. (New) The memory element of claim 29, wherein the motor vehicle has one of front-wheel drive and rear-wheel drive, and the speed variable describing the speed for the at least one driven wheel is determined according to the equation of:

$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$ , where $V_{wheel}$ is a wheel speed of another driven wheel.

33. (New) A computer program for execution on at least one of a computing element and a microprocessor, wherein the computer program is operable to perform a process for determining a speed variable describing a speed of at least one driven wheel of a motor vehicle, the process including:

determining variables describing respective wheel speeds of remaining driven wheels of the motor vehicle;

determining an output rpm variable describing a transmission output rpm of a transmission of the motor vehicle; and

determining the speed variable describing the speed of the at least one driven wheel as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output rpm variable describing the transmission output rpm.

34. (New) The computer program of claim 33, wherein:

the process includes determining an output speed variable specific to a wheel plane and describing an output speed as a function of the transmission output rpm; and

the speed variable describing the speed of the at least one driven wheel is determined as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the output speed variable describing the output speed.

35. (New) The computer program of claim 34, wherein the output speed variable specific to the wheel plane and describing the output speed is determined according to the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} ,$$

where $R_{wheel}$ is a radius of the driven wheels and $I_{Diff}$ is at least one effective differential ratio.

36. (New) The computer program of claim 34, wherein the motor vehicle has all-wheel drive, and the speed variable describing the speed of the at least one driven wheel is determined according to the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} .$$

37. (New) The computer program of claim 34, wherein the motor vehicle has one of front-wheel drive and rear-wheel drive, and the speed variable describing the speed for the at least one driven wheel is determined according to the equation of:

$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$, where $V_{wheel}$ is a wheel speed of another driven wheel.

38. (New) The computer program of claim 33, wherein the computer program is stored on at least one of a memory element and a flash memory.--.

**Remarks**

This Preliminary Amendment cancels without prejudice original claims 1 to 12 in the underlying PCT Application No. PCT/EP00/12365, and adds without prejudice new claims 13 to 38. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. In the Marked Up Version, shading indicates added text and bracketing indicated deleted text. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/EP00/12365 includes an International Search Report, dated March 22, 2001. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

Applicant asserts that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

Dated: 8/8/2001

By: Richard L. Mayer

Richard L. Mayer
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[10191/1961]

# METHOD AND DEVICE FOR DETERMINING A SPEED VARIABLE OF AT LEAST ONE DRIVEN WHEEL OF A MOTOR VEHICLE

## Background Information

The present invention relates to a method and a device for determining a variable which describes the speed of at least one driven wheel of a motor vehicle. Using the method and the device, variables which describe the respective wheel speeds are ascertained for the remaining driven wheels of the motor vehicle. Furthermore, a variable is determined which describes the output rpm of a transmission of the motor vehicle.

The invention also relates to a control unit for a traction control system or a vehicle-dynamics control system of a motor vehicle. To control the drive slip and/or the vehicle dynamics, the control unit determines a variable which describes the speed of at least one driven wheel of the motor vehicle. Variables describing the respective wheel speeds for the remaining driven wheels of the motor vehicle, and a variable describing the output rpm of a transmission of the motor vehicle are available to the control unit.

Furthermore, the present invention relates to a memory element for a control unit of a traction control system or a vehicle-dynamics control system of a motor vehicle. The memory element is constructed in particular as a read-only memory, a random-access memory or a flash memory. Stored in the memory element is a computer program which is executable on a computing element, particularly on a microprocessor.

Finally, the invention also relates to a computer program which is executable on a computing element, particularly on a microprocessor.

## Related Art

Methods and devices for determining a speed variable of at least one driven wheel of a motor vehicle are known in various specific embodiments from the related art.

Thus, for example, the German Patent 196 108 64 A1 describes a method and a device for determining a wheel speed. In that case, the rotational speed of at least one of two wheels of an axle is determined. To that end, a first variable representing the average rotational speed of the two wheels, and a second variable representing the vehicular speed are ascertained. The wheel speed is as a function of a comparison of the difference between a value derived from the first variable and a value derived from the second variable, to a threshold value. Upon falling below the threshold value, the rotational motion of the one wheel is determined at zero, and upon exceeding the threshold value, the rotational motion is determined at a value different from zero.

The ascertainment of the wheel speed known from DE 196 108 64 A1 has the disadvantage that a variable describing the vehicular speed is necessary. To be able to determine a precise wheel speed, a precise determination of the vehicular speed is required. This demands either very accurate estimation methods which determine the vehicular speed, for example, on the basis of the wheel speeds, or else special sensors for detecting the wheel speeds, which, however, require too much effort and are therefore costly. If the vehicular speed is determined as a function of the wheel speeds, only wheel speeds are available as initial quantities, based on which the rotational speed of at least one of two wheels of an axle is determined. Because of this, a systematic error can possibly develop, since a further variable which is independent of the wheel speeds does not go into the determination of the rotational speeds.

The German Patent 197 26 743 A1 describes a method and a device for automatically determining a differential ratio between a transmission of a motor vehicle and the wheels. In that case, a variable describing the speed of at least one wheel, and the output rpm of the transmission are determined. Furthermore, a driving-state variable describing the driving state of the motor vehicle is ascertained. If an essentially steady driving state exists, the variable describing the differential ratio is determined as a function of the variable describing the wheel speed, and the output rpm of the transmission.

The object of the present invention is to improve the ascertainment of a variable describing the wheel speed of at least one driven wheel of a motor vehicle. In particular, the intention is to provide a possibility of making a reliable variable describing the speed magnitude of the wheel available to a traction control system or a vehicle-dynamics control system of a motor vehicle, in spite of the failure of a speed sensor arranged at one of the wheels.

To achieve this objective, starting from the method of the type indicated at the outset, the present invention proposes that for the at least one driven wheel, the variable describing the speed be determined as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm.

## Summary of the Invention

The driven wheels of a motor vehicle are generally fixedly coupled via a differential to the output end of a transmission. This holds true for the front-wheel drive (FWD) and a rear-wheel drive (RWD). In the case of an all-wheel drive (AWD), there is such a fixed coupling only when no slip-encumbered components, such as a viscous coupling, are

integrated into this part of the drive train. This fixed coupling exists in the case of all-wheel-drive vehicles with open differentials.

The variable describing the speed of at least one driven wheel can easily be determined according to the method of the present invention, given a fixed coupling of the driven wheels to the output end of the transmission. To that end, the known variables which describe the respective wheel speeds of the remaining driven wheels are utilized. In addition, the variable describing the transmission output rpm is utilized. As a rule, these variables are available in a control unit for the transmission or for a traction control system or a vehicle-dynamics control system and do not have to be determined separately.

The transmission output rpm is ascertainable with low expenditure and high accuracy. The determination is carried out, for example, by a speed sensor mounted at a suitable location on the transmission.

The method of the present invention can be used to check the performance reliability of wheel-speed sensors of the motor vehicle. For that purpose, the speed variable can be determined in succession for all wheels of the motor vehicle according to the method of the present invention and compared to the speed variable detected by the wheel-speed sensor to be checked.

With the aid of the method of the present invention, an equivalent quantity can be formed for a wheel speed or wheel rotational speed not directly available. For example, a directly determined variable is not available when a wheel-speed sensor is defective. Thus, using the method of the present invention, a reliable speed variable of the wheel can be made available in spite of the failure of a wheel-speed sensor. The system availability of a motor vehicle is thereby

increased, particularly in the event of a wheel-speed sensor malfunction. That is to say, the vehicle continues to be operable in spite of the failure or defect of a wheel-speed sensor. In particular, a reliable quantity describing the speed variable of the wheel can be made available to a traction control system or a vehicle-dynamics control system of a motor vehicle in spite of a malfunction of a wheel-speed sensor. In comparison to previously used traction control systems or vehicle-dynamics control systems, when using the method of the present invention, a system need no longer be switched into the passive state in response to a detected fault in a wheel-speed sensor. The system continues to be available and fully operative, in spite of such a fault or failure of the wheel-speed sensor,.

Such traction control systems or vehicle-dynamics control systems are known, for example, from the publication *"FDR - Die Fahrdynamikregelung von Bosch"* [VDC - The Vehicle Dynamics Control of Bosch] appearing in the Automobiltechnischen Zeitschrift (ATZ) 96, 1994, issue 11, on pp. 674 through 689. The yaw rate of a motor vehicle is controlled using a device described there. To control the yaw rate of the vehicle, the measured yaw rate is compared to a setpoint value for the yaw rate. Using this comparison, a system deviation of the yaw rate is determined, as a function of which driver-independent, wheel-individual braking interventions and/or engine interventions are carried out. Primarily by the driver-independent, wheel-individual braking interventions, a yaw moment is exerted on the vehicle, by which the actual yaw rate comes closer to. In the meantime, the described vehicle-dynamics control system is now also widely referred to as ESP (Electronic Stability Program). The contents of the publication *"FDR - Die Fahrdynamikregelung von Bosch"* are herewith intended to be included ibidem in the description and thus to be part of the description.

In summary, it can be said that: An equivalent quantity is

determined for the speed or the rotational speed of a motor-vehicle wheel having a failed wheel-speed sensor using the sensed rotational speed or speed of the remaining wheels and the output rpm of a transmission. The transmission is preferably an automatic transmission. However, the method of the present invention functions just as well with a manually shifted transmission having a manual or an automatic actuation.

According to one advantageous further development of the present invention, a variable specific to the wheel plane and describing the output speed is determined as a function of the transmission output rpm; and for the at least one driven wheel, the variable describing the speed is determined as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the output speed.

According to a best mode of the invention, the variable specific to the wheel plane and describing the output speed is determined with the aid of the equation

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output}$$

$R_{wheel}$ being the radius of the driven wheels and $I_{Diff}$ being the effective differential ratio(s).

For a motor vehicle having all-wheel drive, the variable describing the speed for the at least one driven wheel is advantageously determined with the aid of the equation

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli}$$

For a motor vehicle having front-wheel drive or rear-wheel drive, the variable describing the speed for the at least one driven wheel is advantageously determined according to the equation

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$$

$V_{wheel}$ being the wheel speed of the driven wheel whose wheel speed is not to be determined, that is to say, whose wheel-speed sensor is not defective.

As a further means for achieving the objective of the present invention, starting from the device of the type indicated at the outset, it is proposed that the device determine the variable describing the speed for the at least one driven wheel as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm.

According to one advantageous further development of the present invention, it is proposed that the device have means for carrying into effect the method according to the invention.

As a further means for achieving the objective of the present invention, starting from the control unit of the type indicated at the outset, it is proposed that the control unit determine the variable describing the speed for the at least one driven wheel as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm.

According to one advantageous further development of the present invention, it is proposed that means for carrying into effect the method according to the invention be implemented in the control unit.

Particularly significant is the implementation of the method according to the present invention in the form of a memory

element that is provided for a control unit of a traction control system or a vehicle-dynamics control system of a motor vehicle. In this context, a computer program that is executable on a computing element, in particular on a microprocessor, and is suitable for carrying out the method according to the present invention, is stored on the memory element. In this case, therefore, the invention is realized by way of a computer program stored on the memory element, so that this memory element provided with the computer program constitutes the invention in the same way as the method for whose accomplishment the computer program is suitable. In particular, an electrical storage medium, for example, a read-only memory, a random-access memory, or a flash memory, can be used as the memory element.

The invention also relates to a computer program that is suitable for carrying out the method according to the present invention when it is executed on a computing element, in particular on a microprocessor. In this context, it is particularly preferred if the computer program is stored on a memory element, in particular on a flash memory.

Brief Description of the Drawing

Additional features, possibilities for use, and advantages of the present invention come to light from the following description of exemplary embodiments of the present invention represented in the Drawing. In this context, all of the described or represented features, alone or in any combination, form the subject matter of the present invention, regardless of their combination in the patent claims or their antecedents, as well as regardless of their formulation and representation in the Specification and Drawing, respectively.

Figure 1 shows a block diagram of a device according to the present invention; and

Figure 2 shows a flow chart of the method according to the present invention.

Description of the Exemplary Embodiments

Figure 1 shows a drive train of a motor vehicle having four wheels 1, 2, 3, 4. The direction of travel of the motor vehicle is indicated by an arrow 20. The front wheels (front-wheel drive, FWD), the rear wheels (rear-wheel drive, RWD) or the front and rear wheels (all-wheel drive, AWD) can be driven in the motor vehicle. The driven wheels of the FWD and of the RWD are generally fixedly coupled via a differential to the output end of a transmission 5. In the case of AWD, there is a fixed coupling only when no slip-encumbered components, such as a viscous-friction coupling (so-called viscous coupling) are integrated into this part of the drive train. This fixed coupling exists in the case of all-wheel-drive vehicles with open differentials. As can be seen in Figure 1, the single-axle-driven motor vehicles, i.e. FWD and RWD motor vehicles, have two differentials 6, 7. All-wheel drive, i.e. AWD vehicles, have three differentials 6, 7, 8.

Both front wheels 1, 2 of the vehicle have wheel speeds $V_{wheel1}$ and $V_{wheel2}$. Both rear wheels have wheels speeds $V_{wheel3}$ and $V_{wheel4}$. The speeds of wheels 1, 2, 3, 4 are determined from rotational speeds $n_{wheel1}$, $n_{wheel2}$, $n_{wheel3}$, $n_{wheel4}$ and from radius $R_{wheel}$ of wheels 1, 2, 3, 4. Instead of radius $R_{wheel}$, it is also possible to utilize the diameter of wheels 1, 2, 3, 4. Rotational speeds $n_{wheel1}$ $n_{wheel2}$, $n_{wheel3}$ $n_{wheel4}$ of wheels 1, 2, 3, 4 are detected by speed sensors 9, 10, 11, 12 which are arranged in the area of wheels 1, 2, 3, 4. Transmission 5 is an automatic transmission.

Transmission 5 is linked via a controller area network (CAN) bus 15, inter alia, to a control unit 14 of a vehicle-dynamics control system 14 that is also widely known as ESP (electronic

stability program). The design and the functioning method of an ESP is described in detail in the publication *"FDR - Die Fahrdynamikregelung von Bosch"*, ibidem, and is herewith intended to be included in the description and thus to be part of the description.

On condition that output rpm $n_{output}$ of automatic transmission 5 is measured by an independent sensor 13 and all driven wheels are coupled in a slip-free manner to the output end of transmission 5, an equivalent quantity for a failed speed sensor 9, 10, 11 or 12 can be formed according to the method of the present invention. A prerequisite for this is that wheel 1, 2, 3 or 4 having the defective speed sensor is a wheel coupled to transmission 5, thus a driven wheel.

To carry out the method of the present invention, control unit 14 has a memory element 16 and a computing element, particularly a microprocessor 17. For example, memory element 16 is constructed as a flash memory. Stored on memory element 16 is a computer program which is executable on microprocessor 17 and is suitable for implementing the method of the present invention. To control the operating-dynamics stability of the motor vehicle, control unit 14 is supplied with input variable 18 which also include, inter alia, wheel speeds $V_{wheel1}$, $V_{wheel2}$, $V_{wheel3}$, $V_{wheel4}$ and output rpm $n_{output}$ of transmission 5. From these input variables 18, control unit 14 determines output quantities 19, for example, for controlling an internal combustion engine, a braking system (particularly an ABS braking system) or a steering system (particularly a steer-by-wire steering system) of the motor vehicle.

In the case of an AWD motor vehicle, the equivalent quantity describing speed $V_{wheelDef}$ of a wheel 1, 2, 3 or 4 having a defective wheel-speed sensor 9, 10, 11 or 12 is determined with the aid of the equation

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli}$$

$V_{output}$ being a variable specific to the wheel plane and describing the output speed of transmission 5, which is determined by the equation

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output}$$

$V_{wheeli}$ is the rotational speed of the remaining driven wheels whose wheel-speed sensors are in working order. That is to say, output speed $V_{output}$ is yielded as a function of output rpm $n_{output}$ and a conversion factor for converting revolutions per minute (R/min) into meters per second (m/s). Output speed $V_{output}$ corresponds to the average value of wheel speeds $V_{wheeli}$ of the driven wheels.

In a motor vehicle having front-wheel drive or rear-wheel drive, the equivalent quantity is determined with the aid of the equation

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$$

$V_{wheel}$ being the wheel speed of the other driven wheel whose wheel-speed sensor is in working order.

Depending on the type of drive of the motor vehicle, effective differential ratio $I_{Diff}$ can be composed of the ratios of differentials 6, 7 and/or 8. In the case of a FWD, it is composed of the two differential ratios $I_{DiffQ}$ of front differential 6 and $I_{Diffmiddle}$ of middle differential 8, and in the case of a RWD, it is composed of the two differential ratios $I_{DiffQ'}$ of rear differential 7 and $I_{Diffmiddle}$ of middle differential 8. In the case of an AWD, all differential ratios $I_{DiffQ}$, $I_{DiffQ'}$ und $I_{Diffmiddle}$ must be taken into account. In this context, differential ratio $I_{Diff}$ is yielded as the product of the individual differential ratios. Allowance must possibly be

made for an effective off-road reduction.

In the event a wheel-speed sensor 9, 10, 11 or 12 is not in working order, an equivalent quantity which describes the speed of the wheel can be calculated for the wheel having the defective wheel-speed sensor using the method of the present invention. Thus, a shutdown of a complete vehicle-dynamics control system or a complete traction control system is no longer necessary. For example, it is conceivable to make an ABS function, i.e. a traction control system which is based solely on braking interventions, possible up to a specific vehicle speed with a defective wheel-speed sensor 9, 10, 11 or 12. The probability of the failure of the complete vehicle is therefore markedly reduced. This holds true in particular for off-road vehicles in which external wheel-speed sensors 9, 10, 11, 12 are subject to particularly high external stress during off-road travel. The shutdown behavior for the ABS case, i.e. the brake-slip control contained in the vehicle-dynamics control, can be developed more favorably, as well.

Figure 2 shows a flowchart of the method according to the present invention. The method begins in a functional block 30. In the following, it is assumed that the motor vehicle has a front-wheel drive (FWD), and the intention is to determine an equivalent quantity describing the speed of wheel 2. To that end, in a functional block 31, first of all a variable specific to the wheel plane and describing output speed $V_{output}$ of transmission 5 is determined. Output speed variable $V_{output}$ is determined as a function of transmission output rpm $n_{output}$ according to the following equation

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output}$$

The equivalent quantity describing speed $V_{wheelDef} = V_{wheel2}$ of wheel 2 is subsequently determined in a functional block 32 according to the following equation

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$$

In this context, $V_{wheel}$ is the speed of wheel 1 having speed sensor 9 in working order. In a functional block 33, the method of the present invention is then brought to an end.

Wheel-speed variable $V_{wheelDef}$, determined with the aid of the method according to the present invention, is compared to wheel speed $V_{wheel2}$ which was detected by speed sensor 10 of wheel 2. If the deviations of the two wheel speeds exceed a specifiable threshold value, a malfunction of speed sensor 10 is assumed. Naturally, wheel-speed variable $V_{wheelDef}$ utilized with the method of the present invention can also be utilized as equivalent quantity for wheel speed $V_{wheel2}$ of wheel 2 in the event speed sensor 10 is defective.

What is claimed is:

1. A method for determining a variable describing the speed ($V_{wheelDef}$) of at least one driven wheel (1, 2, 3, 4) of a motor vehicle, in which the variables describing the respective wheel speeds ($V_{wheeli}$) for the remaining driven wheels of the motor vehicle and a variable describing the output rpm ($n_{output}$) of a transmission (5) of the motor vehicle are determined, wherein the variable describing the speed ($V_{wheelDef}$) for the at least one driven wheel (1, 2, 3, 4) is determined as a function of the variables which describe the respective wheel speeds ($V_{wheeli}$) of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm ($n_{output}$).

2. The method as recited in Claim 1, wherein a variable specific to the wheel plane and describing the output speed ($V_{output}$) is determined as a function of the transmission output rpm ($n_{output}$), and the variable describing the speed ($V_{wheelDef}$) for the at least one driven wheel (1, 2, 3, 4) is determined as a function of the variables which describe the respective wheel speeds ($V_{wheeli}$) of the remaining driven wheels, and as a function of the variable which describes the output speed ($V_{output}$).

3. The method as recited in Claim 2, wherein the variable specific to the wheel plane and describing the output speed ($V_{output}$) is determined according to the equation

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output}$$

$R_{wheel}$ being the radius of the driven wheels and $I_{Diff}$ being the effective differential ratio(s).

4. The method as recited in Claim 2 or 3, wherein in the case of a motor vehicle having all-wheel drive (AWD), the variable

describing the speed ($V_{wheelDef}$) for the at least one driven wheel (1, 2, 3, 4) is determined according to the equation

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli}$$

5. The method as recited in Claim 2 or 3, wherein in the case of a motor vehicle having front-wheel drive (FWD) or having rear-wheel drive (RWD), the variable describing the speed ($V_{wheelDef}$) for the at least one driven wheel (1, 2, 3, 4) is determined according to the equation

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$$

$V_{wheel}$ being the wheel speed of the other driven wheel.

6. A device for determining a variable describing the speed ($V_{wheelDef}$) of at least one driven wheel (1, 2, 3, 4) of a motor vehicle, the device having means (9, 10, 11, 12) for determining variables for the remaining driven wheels of the motor vehicle which describe the respective wheel speeds ($V_{wheeli}$), and means (13) for determining a variable which describes the output rpm ($n_{output}$) of a transmission (5) of the motor vehicle, wherein the device determines the variable describing the speed ($V_{wheelDef}$) for the at least one driven wheel (1, 2, 3, 4) as a function of the variables which describe the respective wheel speeds ($V_{wheeli}$) of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm ($n_{output}$).

7. The device as recited in Claim 6, wherein the device has means for carrying out a method according to one of Claims 2 through 5.

8. A control unit (14) for a traction control system or a vehicle-dynamics control system of a motor vehicle which, to control the drive slip and/or the vehicle dynamics, determines

a variable describing the speed ($V_{wheelDef}$) of at least one driven wheel (1, 2, 3, 4) of the motor vehicle; variables describing the respective wheel speeds ($V_{wheeli}$) for the remaining driven wheels of the motor vehicle and a variable describing the output rpm ($n_{output}$) of a transmission (5) of the motor vehicle being available to the control unit (14), wherein the control unit (14) determines the variable describing the speed ($V_{wheelDef}$) for the at least one driven wheel (1, 2, 3, 4) as a function of the variables which describe the respective wheel speeds ($V_{wheeli}$) of the remaining driven wheels and as a function of the variable which describes the transmission output rpm ($n_{output}$).

9. The control unit (14) as recited in Claim 8, wherein means for carrying out a method according to one of Claims 2 through 5 are implemented in the control unit (14).

10. A memory element (16), particularly a read-only memory, a random-access memory or a flash memory, for a control unit (14) of a traction control system or a vehicle-dynamics control system of a motor vehicle, on which a computer program is stored that is executable on a computing element, particularly on a microprocessor (17), and is suitable for carrying out a method according to one of Claims 1 through 5.

11. A computer program, wherein the computer program is suitable for carrying out a method as defined in one of Claims 1 through 5 when it is executed on a computing element, in particular on a microprocessor (17).

12. The computer program as defined in Claim 11, wherein the computer program is stored on a memory element (16), in particular on a flash memory.

## Abstract

The invention relates to a method and a device for determining a variable describing the speed ($V_{wheelDef}$) of at least one driven wheel (1, 2, 3, 4) of a motor vehicle. In this context, variables describing the respective wheel speeds ($V_{wheeli}$) for the remaining driven wheels of the motor vehicle, and a variable describing the output rpm ($n_{output}$) of a transmission (5) of the motor vehicle are determined. To be able to make a reliable variable describing the speed magnitude of the wheel (1, 2, 3, 4) available to a traction control system or a vehicle-dynamics control system of a motor vehicle in spite of the failure of a speed sensor (9, 10, 11, 12) arranged at one of the wheels, it is proposed that the variable describing the speed ($V_{wheelDef}$) for the at least one driven wheel (1, 2, 3, 4) be determined as a function of the variables which describe the respective wheel speeds ($V_{wheeli}$) of the remaining driven wheels and as a function of the variable which describes the transmission output rpm ($n_{output}$).

(Figure 1)

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# METHOD AND DEVICE FOR DETERMINING A SPEED VARIABLE OF AT LEAST ONE DRIVEN WHEEL OF A MOTOR VEHICLE

## FIELD OF THE INVENTION

The present invention relates to a method and a device for determining a variable describing the speed of at least one driven wheel of a motor vehicle, for ascertaining variables describing the respective wheel speeds for the remaining driven wheels of the motor vehicle, and for determining a variable describing the output rpm of a transmission of the motor vehicle. The present invention also relates to a control unit for a traction control system or a vehicle-dynamics control system of a motor vehicle. To control the drive slip and/or the vehicle dynamics, the control unit determines a variable describing the speed of at least one driven wheel of the motor vehicle. Variables describing the respective wheel speeds for the remaining driven wheels of the motor vehicle, and a variable describing the output rpm of a transmission of the motor vehicle are available to the control unit. The present invention also relates to a memory element for a control unit of a traction control system or a vehicle-dynamics control system of a motor vehicle. The memory element may be a read-only memory, a random-access memory or a flash memory. Stored in the memory element is a computer program that is executable on a computing element, including a microprocessor. Finally, the present invention also relates to a computer program that is executable on a computing element, including a microprocessor.

## BACKGROUND INFORMATION

It is believed that various methods and devices for determining a speed variable of at least one driven wheel of a motor vehicle are available.

**SUBSTITUTE SPECIFICATION**

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Thus, for example, German Published Patent Application No. 196 108 64 discusses a method and a device for determining a wheel speed. In that case, the rotational speed of at least one of two wheels of an axle is determined. To that end, a first variable representing the average rotational speed of the two wheels, and a second variable representing the vehicular speed are ascertained. The wheel speed is determined as a function of a comparison of a threshold value and of the difference between a value derived from the first variable and a value derived from the second variable. Upon falling below the threshold value, the rotational motion of the one wheel is determined at zero, and upon exceeding the threshold value, the rotational motion is determined at a value different from zero.

It is believed, however, that ascertaining the wheel speed as above may have the disadvantage that a variable describing the vehicular may be speed is necessary. To be able to determine a precise wheel speed, it is believed that a precise determination of the vehicular speed may be required. This may demand either very accurate estimation methods for determining the vehicular speed, for example, on the basis of the wheel speeds, or else special sensors for detecting the wheel speeds, which, however, may require too much effort and therefore may be costly. If the vehicular speed is determined as a function of the wheel speeds, only wheel speeds are available as initial quantities, based on which the rotational speed of at least one of two wheels of an axle is determined. Because of this, a systematic error may develop, since a further variable which is independent of the wheel speeds may not go into the determination of the rotational speeds.

In German Published Patent Application No. 197 26 743 is discussed a method and a device for automatically determining a differential ratio between a transmission of a motor vehicle

and the wheels. In that case, a variable describing the speed of at least one wheel, and the output rpm of the transmission are determined. Furthermore, a driving-state variable describing the driving state of the motor vehicle is ascertained. If an essentially steady driving state exists, the variable describing the differential ratio is determined as a function of the variable describing the wheel speed, and the output rpm of the transmission.

An object of an exemplary embodiment and/or exemplary method of the present invention is to ascertain a variable describing the wheel speed of at least one driven wheel of a motor vehicle. In particular, it is believed that the foregoing provides for making a reliable variable describing the speed magnitude of the wheel available to a traction control system or a vehicle-dynamics control system of a motor vehicle, in spite of the failure of a speed sensor arranged at one of the wheels.

In particular, for the at least one driven wheel, the variable describing the speed may be determined as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the variable describing the transmission output rpm.

SUMMARY OF THE INVENTION

The driven wheels of a motor vehicle may be fixedly coupled via a differential to the output end of a transmission, including for front-wheel drive (FWD) and for rear-wheel drive (RWD). In the case of all-wheel drive (AWD), there may be such a fixed coupling only when no slip-encumbered components, such as a viscous coupling, are integrated into this part of the drive train. This fixed coupling exists in the case of all-wheel-drive vehicles with open differentials.

The variable describing the speed of at least one driven wheel

may be determined according to the exemplary method of the present invention, given a fixed coupling of the driven wheels to the output end of the transmission. To that end, the known variables describing the respective wheel speeds of the remaining driven wheels are used. In addition, the variable describing the transmission output rpm is used. These variables are available in a control unit for the transmission, for a traction control system or for a vehicle-dynamics control system, and do not have to be determined separately.

The transmission output rpm is ascertainable with low expenditure and high accuracy. The determination is carried out, for example, by a speed sensor mounted at a suitable location on the transmission.

The exemplary method of the present invention can be used to check the performance reliability of wheel-speed sensors of the motor vehicle. For that purpose, the speed variable can be determined in succession for all wheels of the motor vehicle according to the exemplary method of the present invention and compared to the speed variable detected by the wheel-speed sensor to be checked.

Using the exemplary method of the present invention, a corresponding or comparable quantity can be formed for a wheel speed or wheel rotational speed not directly available. For example, a directly determined variable may not be available when a wheel-speed sensor is defective. Thus, using the exemplary method of the present invention, a reliable speed variable of the wheel can be made available in spite of the failure of a wheel-speed sensor. The system availability of a motor vehicle may thereby be increased, particularly in the event of a wheel-speed sensor malfunction. That is to say, the vehicle may continue to be operable in spite of the failure or defect of a wheel-speed sensor. In particular, a

reliable quantity describing the speed variable of the wheel can be made available to a traction control system or a vehicle-dynamics control system of a motor vehicle in spite of a malfunction of a wheel-speed sensor. In comparison to previously used traction control systems or vehicle-dynamics control systems, when using the exemplary method of the present invention, it is believed that a system need no longer be switched into the passive state in response to a detected fault in a wheel-speed sensor. The system should continue to be available and fully operative, in spite of such a fault or failure of the wheel-speed sensor.

Such traction control systems or vehicle-dynamics control systems are discussed, for example, in the publication *"FDR - Die Fahrdynamikregelung von Bosch"* (VDC - The Vehicle Dynamics Control of Bosch) appearing in the Automobiltechnischen Zeitschrift (ATZ) 96, 1994, issue 11, on pp. 674 through 689. The yaw rate of a motor vehicle is controlled using a device discussed in that reference. To control the yaw rate of the vehicle, the measured yaw rate is compared to a setpoint value for the yaw rate. Using this comparison, a system deviation of the yaw rate is determined, as a function of which driver-independent, wheel-individual braking interventions and/or engine interventions are carried out. What may be primarily by the driver-independent, wheel-individual braking interventions, a yaw moment is exerted on the vehicle, by which the actual yaw rate comes closer to the setpoint value. The foregoing vehicle-dynamics control system is also referred to as ESP (Electronic Stability Program). The contents of the publication *"FDR - Die Fahrdynamikregelung von Bosch"* are incorporated by reference.

In summary, an equivalent (that is, corresponding or comparable) quantity is determined for the speed or the rotational speed of a motor-vehicle wheel having a failed wheel-speed sensor using the sensed rotational speed or speed

of the remaining wheels and the output rpm of a transmission. The transmission may be an automatic transmission. However, the exemplary method of the present invention functions just as well with a manually shifted transmission having a manual or an automatic actuation.

According to another exemplary method of the present invention, a variable specific to the wheel plane and describing the output speed is determined as a function of the transmission output rpm. For the at least one driven wheel, the variable describing the speed is determined as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the variable describing the output speed.

According to another exemplary embodiment of the present invention, the variable specific to the wheel plane and describing the output speed is determined using the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} ,$$

where $R_{wheel}$ is the radius of the driven wheels and $I_{Diff}$ is the effective differential ratio(s).

For a motor vehicle having all-wheel drive, the variable describing the speed for the at least one driven wheel may be advantageously determined using the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} .$$

For a motor vehicle having front-wheel drive or rear-wheel drive, the variable describing the speed for the at least one driven wheel may be advantageously determined according to the equation:

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel},$$

where $V_{wheel}$ is the wheel speed of the driven wheel whose wheel speed is not to be determined, that is to say, whose wheel-speed sensor is not defective.

Further, starting from the device indicated at the outset, the exemplary device determines the variable describing the speed for the at least one driven wheel as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the variable describing the transmission output rpm.

According to another exemplary embodiment of the present invention, the device includes an apparatus, arrangement or structure for performing the exemplary method according to the present invention.

Further, starting from the control unit indicated at the outset, the exemplary control unit determines the variable describing the speed for the at least one driven wheel as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the variable describing the transmission output rpm.

According to another exemplary embodiment of the present invention, the apparatus, arrangement or structure for performing the exemplary method according to the present invention is implemented in the control unit.

The exemplary method according to the present invention may be implemented in the form of a memory element that is provided for a control unit of a traction control system or a vehicle-dynamics control system of a motor vehicle. In this context, a computer program that is executable on a computing

element, in particular on a microprocessor, and that is suitable for carrying out or performing the exemplary method according to the present invention, is stored at, in or on the memory element. In this case, therefore, the exemplary embodiment of the present invention is realized by way of a computer program stored at, in or on the memory element, so that this memory element, as provided with the computer program, constitutes the exemplary embodiment of the present invention in the same way as the exemplary method for whose accomplishment the computer program is suitable. In particular, an electrical storage medium, for example, a read-only memory, a random-access memory, or a flash memory, can be used as the memory element.

The exemplary embodiment of the invention also relates to a computer program that is suitable for carrying out the exemplary method according to the present invention when it is executed on a computing element, in particular on a microprocessor. In this context, the computer program may be stored in a memory element, in particular in a flash memory.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a block diagram of an exemplary device according to the present invention.

Figure 2 shows a flow chart of an exemplary method according to the present invention.

DETAILED DESCRIPTION

Figure 1 shows a drive train of a motor vehicle having four wheels 1, 2, 3, 4. The direction of travel of the motor vehicle is indicated by an arrow 20. The front wheels (front-wheel drive, FWD), the rear wheels (rear-wheel drive, RWD) or the front and rear wheels (all-wheel drive, AWD) can be driven in the motor vehicle. The driven wheels of the FWD and of the RWD may be fixedly coupled via a differential to

the output end of a transmission 5. In the case of AWD, there is a fixed coupling only when no slip-encumbered components, such as a viscous-friction coupling (so-called viscous coupling), are integrated into this part of the drive train. This fixed coupling is provided in all-wheel-drive vehicles with open differentials. As can be seen in Figure 1, the single-axle-driven motor vehicles, i.e., FWD and RWD motor vehicles, have two differentials 6, 7. All-wheel drive, i.e., AWD vehicles, have three differentials 6, 7, 8.

Both front wheels 1, 2 of the vehicle have wheel speeds $V_{wheel1}$ and $V_{wheel2}$. Both rear wheels have wheels speeds $V_{wheel3}$ and $V_{wheel4}$. The speeds of wheels 1, 2, 3, 4 are determined from rotational speeds $n_{wheel1}$, $n_{wheel2}$, $n_{wheel3}$, $n_{wheel4}$ and from radius $R_{wheel}$ of wheels 1, 2, 3, 4. Instead of radius $R_{wheel}$, it is also possible to use the diameter of wheels 1, 2, 3, 4. Rotational speeds $n_{wheel1}$ $n_{wheel2}$, $n_{wheel3}$ $n_{wheel4}$ of wheels 1, 2, 3, 4 are detected by speed sensors 9, 10, 11, 12 that are arranged in the area of wheels 1, 2, 3, 4. Transmission 5 is an automatic transmission.

Transmission 5 is linked via a controller area network (CAN) bus 15, in part, to a control unit 14 of a vehicle-dynamics control system 14, which is also referred to as ESP (electronic stability program). The design and the functioning method of an ESP is discussed in the publication *"FDR - Die Fahrdynamikregelung von Bosch"*, which is incorporated by reference.

On condition that output rpm $n_{output}$ of automatic transmission 5 is measured by an independent sensor 13 and all driven wheels are coupled in a slip-free manner to the output end of transmission 5, a quantity for a failed speed sensor 9, 10, 11 or 12 can be formed according to the exemplary method of the present invention. A prerequisite for this is that wheel 1, 2, 3 or 4 having the defective speed sensor is a wheel coupled to transmission 5, thus a driven wheel.

To carry out or perform the exemplary method of the present invention, control unit 14 has a memory element 16 and a computing element, particularly a microprocessor 17. For example, memory element 16 may be a flash memory. Stored on memory element 16 is a computer program that is executable on microprocessor 17 and that is suitable for implementing the method of the present invention. To control the operating-dynamics stability of the motor vehicle, control unit 14 is supplied with input variables 18 which also include, in part, wheel speeds $V_{wheel1}$, $V_{wheel2}$, $V_{wheel3}$, $V_{wheel4}$ and output rpm $n_{output}$ of transmission 5. From these input variables 18, control unit 14 determines output quantities 19, for example, for controlling an internal combustion engine, a braking system (particularly an ABS braking system) or a steering system (particularly a steer-by-wire steering system) of the motor vehicle.

In the case of an AWD motor vehicle, the corresponding or comparable (or equivalent) quantity describing speed $V_{wheelDef}$ of a wheel 1, 2, 3 or 4 having a defective wheel-speed sensor 9, 10, 11 or 12 is determined using the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} ,$$

where $V_{output}$ is a variable specific to the wheel plane and describing the output speed of transmission 5, which is determined by the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} ,$$

where $V_{wheeli}$ is the rotational speed of the remaining driven wheels whose wheel-speed sensors are in working order. That is, output speed $V_{output}$ is yielded as a function of output rpm $n_{output}$ and a conversion factor for converting revolutions per minute (R/min) into meters per second (m/s). Output speed $V_{output}$

corresponds to the average value of wheel speeds $V_{wheeli}$ of the driven wheels.

In a motor vehicle having front-wheel drive or rear-wheel drive, the corresponding or comparable quantity is determined using the equation of:

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel} ,$$

where $V_{wheel}$ is the wheel speed of the other driven wheel whose wheel-speed sensor is in working order.

Depending on the type of drive of the motor vehicle, effective differential ratio $I_{Diff}$ can be composed of the ratios of differentials 6, 7 and/or 8. In the case of a FWD, it is composed of the two differential ratios $I_{DiffQ}$ of front differential 6 and $I_{Diffmiddle}$ of middle differential 8, and in the case of a RWD, it is composed of the two differential ratios $I_{DiffQ'}$ of rear differential 7 and $I_{Diffmiddle}$ of middle differential 8. In the case of an AWD, all differential ratios $I_{DiffQ}$, $I_{DiffQ'}$ und $I_{Diffmiddle}$ must be taken into account or combined. In this context, differential ratio $I_{Diff}$ is yielded as the product of the individual differential ratios. Allowance may need to be made for an effective off-road reduction.

If a wheel-speed sensor 9, 10, 11 or 12 is not in working order, the corresponding or comparable (or equivalent) quantity describing the speed of the wheel can be calculated for the wheel having the defective wheel-speed sensor using the exemplary method of the present invention. Thus, a shutdown of a complete vehicle-dynamics control system or a complete traction control system should not be necessary. For example, an ABS function, i.e., a traction control system which is based solely on braking interventions, may be provided up to a specific vehicle speed with a defective wheel-speed sensor 9, 10, 11 or 12. The probability of the

failure of the complete vehicle should therefore be markedly reduced. This should hold true in particular for off-road vehicles in which external wheel-speed sensors 9, 10, 11, 12 may be subject to particularly high external stress during off-road travel. The shutdown behavior for the ABS case, i.e., the brake-slip control contained in the vehicle-dynamics control, may also be developed more favorably.

Figure 2 shows a flowchart of the exemplary method according to the present invention. The exemplary method begins in a functional block 30. In the following, it is assumed that the motor vehicle has a front-wheel drive (FWD), and a corresponding or comparable quantity describing the speed of wheel 2 must be determined. To that end, in a functional block 31, a variable specific to the wheel plane and describing output speed $V_{output}$ of transmission 5 is first determined. Output speed variable $V_{output}$ is determined as a function of transmission output rpm $n_{output}$ according to the following equation:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} \, .$$

The corresponding or comparable (or equivalent) quantity describing speed $V_{wheelDef} = V_{wheel2}$ of wheel *2* is subsequently determined in a functional block 32 according to the following equation:

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel} \, .$$

In this context, $V_{wheel}$ is the speed of wheel 1 having speed sensor 9 in working order. In a functional block 33, the exemplary method of the present invention is then brought to an end.

Wheel-speed variable $V_{wheelDef}$, determined using the exemplary

method according to the present invention, is compared to wheel speed $V_{wheel2}$ detected by speed sensor 10 of wheel 2. If the deviations of the two wheel speeds exceed a specifiable threshold value, a malfunction of speed sensor 10 is assumed. Wheel-speed variable $V_{wheelDef}$ used with the exemplary method of the present invention can also be used as a corresponding or comparable (or equivalent) quantity for wheel speed $V_{wheel2}$ of wheel 2 if speed sensor 10 is defective.

ABSTRACT OF THE DISCLOSURE

A method and a device for determining a variable describing the speed at least one driven wheel of a motor vehicle. In this context, variables describing the respective wheel speeds for the remaining driven wheels of the motor vehicle, and a variable describing the output rpm of a transmission of the motor vehicle are determined. To be able to make a reliable variable describing the speed magnitude of the wheel available to a traction control system or a vehicle-dynamics control system of a motor vehicle in spite of the failure of a speed sensor arranged at one of the wheels, the variable describing the speed for the at least one driven wheel is determined as a function of the variables describing the respective wheel speeds of the remaining driven wheels and as a function of the variable describing the transmission output rpm.

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[10191/1961]

# METHOD AND DEVICE FOR DETERMINING A SPEED VARIABLE OF AT LEAST ONE DRIVEN WHEEL OF A MOTOR VEHICLE

[Background Information
]FIELD OF THE INVENTION

The present invention relates to a method and a device for determining a variable [which describes]describing the speed of at least one driven wheel of a motor vehicle[. Using the method and the device,], for ascertaining variables [which describe]describing the respective wheel speeds[ are ascertained] for the remaining driven wheels of the motor vehicle[. Furthermore,], and for determining a variable [is determined which describes]describing the output rpm of a transmission of the motor vehicle.[

]The present invention also relates to a control unit for a traction control system or a vehicle-dynamics control system of a motor vehicle. To control the drive slip and/or the vehicle dynamics, the control unit determines a variable [which describes]describing the speed of at least one driven wheel of the motor vehicle. Variables describing the respective wheel speeds for the remaining driven wheels of the motor vehicle, and a variable describing the output rpm of a transmission of the motor vehicle are available to the control unit.[

Furthermore, t] The present invention also relates to a memory element for a control unit of a traction control system or a vehicle-dynamics control system of a motor vehicle. The memory element [is constructed in particular as]may be a read-only memory, a random-access memory or a flash memory. Stored in the memory element is a computer program [which]that is executable on a computing element, [particularly on]including a microprocessor.[

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] Finally, the present invention also relates to a computer program [which]that is executable on a computing element, [particularly on]including a microprocessor.

[Related Art

Methods]BACKGROUND INFORMATION

It is believed that various methods and devices for determining a speed variable of at least one driven wheel of a motor vehicle are [known in various specific embodiments from the related art]available.

Thus, for example, [the ]German Published Patent Application No. 196 108 64 [A1 describes]discusses a method and a device for determining a wheel speed. In that case, the rotational speed of at least one of two wheels of an axle is determined. To that end, a first variable representing the average rotational speed of the two wheels, and a second variable representing the vehicular speed are ascertained. The wheel speed is[] determined as a function of a comparison of a threshold value and of the difference between a value derived from the first variable and a value derived from the second variable[, to a threshold value]. Upon falling below the threshold value, the rotational motion of the one wheel is determined at zero, and upon exceeding the threshold value, the rotational motion is determined at a value different from zero.

[

The ascertainment of]

It is believed, however, that ascertaining the wheel speed [known from

DE 196 108 64 A1]as above may ha[s]ve the disadvantage that a variable describing the vehicular may be speed is necessary. To be able to determine a precise wheel speed, it is believed

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that a precise determination of the vehicular speed [is]may be required. This may demand[s] either very accurate estimation methods [which determine]for determining the vehicular speed, for example, on the basis of the wheel speeds, or else special sensors for detecting the wheel speeds, which, however, may require too much effort and [are ]therefore may be costly. If the vehicular speed is determined as a function of the wheel speeds, only wheel speeds are available as initial quantities, based on which the rotational speed of at least one of two wheels of an axle is determined. Because of this, a systematic error [can possibly]may develop, since a further variable which is independent of the wheel speeds [does]may not go into the determination of the rotational speeds.

[The]In German Published Patent Application No. 197 26 743 [A1 describes]is discussed a method and a device for automatically determining a differential ratio between a transmission of a motor vehicle and the wheels. In that case, a variable describing the speed of at least one wheel, and the output rpm of the transmission are determined. Furthermore, a driving-state variable describing the driving state of the motor vehicle is ascertained. If an essentially steady[ ] driving state exists, the variable describing the differential ratio is determined as a function of the variable describing the wheel speed, and the output rpm of the transmission.

[The]An object of an exemplary embodiment and/or exemplary method of the present invention is to [improve the ascertainment of]ascertain a variable describing the wheel speed of at least one driven wheel of a motor vehicle. In particular, it is believed that the [intention is to]foregoing provide[ a possibility of]s for making a reliable variable describing the speed magnitude of the wheel available to a traction control system or a vehicle-dynamics control system of a motor vehicle, in spite of the failure of a speed sensor

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arranged at one of the wheels.

[To achieve this objective, starting from the method of the type indicated at the outset, the present invention proposes that]In particular, for the at least one driven wheel, the variable describing the speed may be determined as a function of the variables [which describe]describing the respective wheel speeds of the remaining driven wheels, and as a function of the variable [which describes]describing the transmission output rpm.

[Summary of the Invention
]<u>SUMMARY OF THE INVENTION</u>
The driven wheels of a motor vehicle [are generally]may be fixedly coupled via a differential to the output end of a transmission[. This holds true], including for[ the] front-wheel drive (FWD) and [a]for rear-wheel drive (RWD). In the case of [an ]all-wheel drive (AWD), there [is]may be such a fixed coupling only when no slip-encumbered components, such as a viscous coupling, are integrated into this part of the drive train. This fixed coupling exists in the case of all-wheel-drive vehicles with open differentials.

The variable describing the speed of at least one driven wheel [can easily]may be determined according to the exemplary method of the present invention, given a fixed coupling of the driven wheels to the output end of the transmission. To that end, the known variables [which describe]describing the respective wheel speeds of the remaining driven wheels are [utilized]used. In addition, the variable describing the transmission output rpm is [utilized]used. [As a rule, t]These variables are available in a control unit for the transmission[ or], for a traction control system [or]or for a vehicle-dynamics control system, and do not have to be determined separately.

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The transmission output rpm is ascertainable with low expenditure and high accuracy. The determination is carried out, for example, by a speed sensor mounted at a suitable location on the transmission.

The exemplary method of the present invention can be used to check the performance reliability of wheel-speed sensors of the motor vehicle. For that purpose, the speed variable can be determined in succession for all wheels of the motor vehicle according to the exemplary method of the present invention and compared to the speed variable detected by the wheel-speed sensor to be checked.

[With]Using the [aid of the]exemplary method of the present invention, [an equivalent]a corresponding or comparable quantity can be formed for a wheel speed or wheel rotational speed not directly available. For example, a directly determined variable [is]may not be available when a wheel-speed sensor is defective. Thus, using the exemplary method of the present invention, a reliable speed variable of the wheel can be made available in spite of the failure of a wheel-speed sensor. The system availability of a motor vehicle [is]may thereby be increased, particularly in the event of a wheel-speed sensor malfunction. That is to say, the vehicle may continue[s] to be operable in spite of the failure or defect of a wheel-speed sensor. In particular, a reliable quantity describing the speed variable of the wheel can be made available to a traction control system or a vehicle-dynamics control system of a motor vehicle in spite of a malfunction of a wheel-speed sensor. In comparison to previously used traction control systems or vehicle-dynamics control systems, when using the exemplary method of the present invention, it is believed that a system need no longer be switched into the passive state in response to a detected fault in a wheel-speed sensor. The system should continue[s]

to be available and fully operative, in spite of such a fault or failure of the wheel-speed sensor[,].

Such traction control systems or vehicle-dynamics control systems are [known]discussed, for example, [from]in the publication *"FDR - Die Fahrdynamikregelung von Bosch"* [[](VDC - The Vehicle Dynamics Control of Bosch[]]) appearing in the Automobiltechnischen Zeitschrift (ATZ) 96, 1994, issue 11, on pp. 674 through 689. The yaw rate of a motor vehicle is controlled using a device [described there]discussed in that reference. To control the yaw rate of the vehicle, the measured yaw rate is compared to a setpoint value for the yaw rate. Using this comparison, a system deviation of the yaw rate is determined, as a function of which driver-independent, wheel-individual braking interventions and/or engine interventions are carried out. [P]What may be primarily by the driver-independent, wheel-individual braking interventions, a yaw moment is exerted on the vehicle, by which the actual yaw rate comes closer to[. In] the [meantime, t]setpoint value. The [described]foregoing vehicle-dynamics control system is [now ]also[ widely] referred to as ESP (Electronic Stability Program). The contents of the publication *"FDR - Die Fahrdynamikregelung von Bosch"* are [herewith intended to be included ibidem in the description and thus to be part of the description.

In summary, it can be said that: An equivalent]incorporated by reference.

In summary, an equivalent (that is, corresponding or comparable) quantity is determined for the speed or the rotational speed of a motor-vehicle wheel having a failed wheel-speed sensor using the sensed rotational speed or speed

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of the remaining wheels and the output rpm of a transmission. The transmission [is preferably]may be an automatic transmission. However, the exemplary method of the present invention functions just as well with a manually shifted transmission having a manual or an automatic actuation.

According to [one advantageous further development]another exemplary method of the present invention, a variable specific to the wheel plane and describing the output speed is determined as a function of the transmission output rpm[; and f]. For the at least one driven wheel, the variable describing the speed is determined as a function of the variables [which describe]describing the respective wheel speeds of the remaining driven wheels, and as a function of the variable [which describes]describing the output speed.

According to [a best mode]another exemplary embodiment of the present invention, the variable specific to the wheel plane and describing the output speed is determined [with the aid of]using the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} \quad ,$$

where $R_{wheel}$ [being]is the radius of the driven wheels and $I_{Diff}$ [being]is the effective differential ratio(s).

For a motor vehicle having all-wheel drive, the variable describing the speed for the at least one driven wheel [is]may be advantageously determined [with the aid of]using the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} \ .$$

For a motor vehicle having front-wheel drive or rear-wheel

drive, the variable describing the speed for the at least one driven wheel [is]may be advantageously determined according to the equation:

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel},$$

where $V_{wheel}$ [being]is the wheel speed of the driven wheel whose wheel speed is not to be determined, that is to say, whose wheel-speed sensor is not defective.

[As a further means for achieving the objective]Further, starting from the device indicated at the outset, the exemplary device determines the variable describing the speed for the at least one driven wheel as a function of the variables describing the respective wheel speeds of the remaining driven wheels, and as a function of the variable describing the transmission output rpm.

According to another exemplary embodiment of the present invention, the device includes an apparatus, arrangement or structure for performing the exemplary method according to the present invention.

Further, starting from the [device of the type]control unit indicated at the outset, [it is proposed that ]the [device]exemplary control unit determines the variable describing the speed for the at least one driven wheel as a function of the variables [which describe]describing the respective wheel speeds of the remaining driven wheels, and as a function of the variable [which describes]describing the transmission output rpm.

According to [one advantageous further development]another exemplary embodiment of the present invention, [it is proposed

that]the apparatus, arrangement or structure for performing the [device have means for carrying into effect the]exemplary method according to the [invention.

As a further means for achieving the objective of the present invention, starting from the control unit of the type indicated at the outset, it is proposed that the control unit determine the variable describing the speed for the at least one driven wheel as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm.

According to one advantageous further development of the present invention, it is proposed that means for carrying into effect the method according to the invention be]present invention is implemented in the control unit.

[Particularly significant is the implementation of the]The exemplary method according to the present invention may be implemented in the form of a memory element that is provided for a control unit of a traction control system or a vehicle-dynamics control system of a motor vehicle. In this context, a computer program that is executable on a computing element, in particular on a microprocessor, and that is suitable for carrying out or performing the exemplary method according to the present invention, is stored at, in or on the memory element. In this case, therefore, the exemplary embodiment of the present invention is realized by way of a computer program stored at, in or on the memory element, so that this memory element, as provided with the computer program, constitutes the exemplary embodiment of the present invention in the same way as the exemplary method for whose accomplishment the computer program is suitable. In particular, an electrical storage medium, for example, a

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read-only memory, a random-access memory, or a flash memory, can be used as the memory element.

The exemplary embodiment of the invention also relates to a computer program that is suitable for carrying out the exemplary method according to the present invention when it is executed on a computing element, in particular on a microprocessor. In this context, [it is particularly preferred if ]the computer program [is]may be stored [on]in a memory element, in particular [on]in a flash memory.

[Brief Description of the Drawing

Additional features, possibilities for use, and advantages of the present invention come to light from the following description of exemplary embodiments of the present invention represented in the Drawing. In this context, all of the described or represented features, alone or in any combination, form the subject matter of the present invention, regardless of their combination in the patent claims or their antecedents, as well as regardless of their formulation and representation in the Specification and Drawing, respectively.

Figure 1 ]<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

Figure 1 shows a block diagram of [a]an exemplary device according to the present invention[; and].

Figure 2[ ] shows a flow chart of [the]an exemplary method according to the present invention.

[Description of the Exemplary Embodiments
]<u>DETAILED DESCRIPTION</u>

Figure 1 shows a drive train of a motor vehicle having four wheels 1, 2, 3, 4. The direction of travel of the motor vehicle is indicated by an arrow 20. The front wheels

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(front-wheel drive, FWD), the rear wheels (rear-wheel drive, RWD) or the front and rear wheels (all-wheel drive, AWD) can be driven in the motor vehicle. The driven wheels of the FWD and of the RWD [are generally]may be fixedly coupled via a differential to the output end of a transmission 5. In the case of AWD, there is a fixed coupling only when no slip-encumbered components, such as a viscous-friction coupling (so-called viscous coupling), are integrated into this part of the drive train. This fixed coupling [exists]is provided in[ the case of] all-wheel-drive vehicles with open differentials. As can be seen in Figure 1, the single-axle-driven motor vehicles, i.e., FWD and RWD motor vehicles, have two differentials 6, 7. All-wheel drive, i.e., AWD vehicles, have three differentials 6, 7, 8.

Both front wheels 1, 2 of the vehicle have wheel speeds $V_{wheel1}$ and $V_{wheel2}$. Both rear wheels have wheels speeds $V_{wheel3}$ and $V_{wheel4}$. The speeds of wheels 1, 2, 3, 4 are determined from rotational speeds $n_{wheel1}$, $n_{wheel2}$, $n_{wheel3}$, $n_{wheel4}$ and from radius $R_{wheel}$ of wheels 1, 2, 3, 4. Instead of radius $R_{wheel}$, it is also possible to [utilize]use the diameter of wheels 1, 2, 3, 4. Rotational speeds $n_{wheel1}$ $n_{wheel2}$, $n_{wheel3}$ $n_{wheel4}$ of wheels 1, 2, 3, 4 are detected by speed sensors 9, 10, 11, 12 [which]that are arranged in the area of wheels 1, 2, 3, 4. Transmission 5 is an automatic transmission.

Transmission 5 is linked via a controller area network (CAN) bus 15, [inter alia]in part, to a control unit 14 of a vehicle-dynamics control system 14[ that], which is also [widely known]referred to as ESP (electronic stability program). The design and the functioning method of an ESP is [described in detail]discussed in the publication *"FDR - Die Fahrdynamikregelung von Bosch"*, [ibidem, and is herewith intended to be included in the description and thus to be part of the description]which is incorporated by reference.

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On condition that output rpm $n_{output}$ of automatic transmission 5 is measured by an independent sensor 13 and all driven wheels are coupled in a slip-free manner to the output end of transmission 5, [an equivalent]a quantity for a failed speed sensor 9, 10, 11 or 12 can be formed according to the exemplary method of the present invention. A prerequisite for this is that wheel 1, 2, 3 or 4 having the defective speed sensor is a wheel coupled to transmission 5, thus a driven wheel.

To carry out or perform the exemplary method of the present invention, control unit 14 has a memory element 16 and a computing element, particularly a microprocessor 17. For example, memory element 16 [is constructed as]may be a flash memory. Stored on memory element 16 is a computer program [which]that is executable on microprocessor 17 and that is suitable for implementing the method of the present invention. To control the operating-dynamics stability of the motor vehicle, control unit 14 is supplied with input variable[]s 18 which also include, [inter alia]in part, wheel speeds $V_{wheel1}$, $V_{wheel2}$, $V_{wheel3}$, $V_{wheel4}$ and output rpm $n_{output}$ of transmission 5. From these input variables 18, control unit 14 determines output quantities 19, for example, for controlling an internal combustion engine, a braking system (particularly an ABS braking system) or a steering system (particularly a steer-by-wire steering system) of the motor vehicle.

In the case of an AWD motor vehicle, the corresponding or comparable (or equivalent) quantity describing speed $V_{wheelDef}$ of a wheel 1, 2, 3 or 4 having a defective wheel-speed sensor 9, 10, 11 or 12 is determined [with the aid of]using the equation of:

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli} \ ,$$

where $V_{output}$ [being]is a variable specific to the wheel plane and describing the output speed of transmission 5, which is determined by the equation of:

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} \ ,$$

where $V_{wheeli}$ is the rotational speed of the remaining driven wheels whose wheel-speed sensors are in working order. That is[ to say], output speed $V_{output}$ is yielded as a function of output rpm $n_{output}$ and a conversion factor for converting revolutions per minute (R/min) into meters per second (m/s). Output speed $V_{output}$ corresponds to the average value of wheel speeds $V_{wheeli}$ of the driven wheels.

In a motor vehicle having front-wheel drive or rear-wheel drive, the [equivalent]corresponding or comparable quantity is determined [with the aid of]using the equation of:

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel} \ ,$$

where $V_{wheel}$ [being]is the wheel speed of the other driven wheel whose wheel-speed sensor is in working order.

Depending on the type of drive of the motor vehicle, effective differential ratio $I_{Diff}$ can be composed of the ratios of differentials 6, 7 and/or 8. In the case of a FWD, it is composed of the two differential ratios $I_{DiffQ}$ of front differential 6 and $I_{Diffmiddle}$ of middle differential 8, and in the case of a RWD, it is composed of the two differential ratios $I_{DiffQ'}$ of rear differential 7 and $I_{Diffmiddle}$ of middle differential 8. In the case of an AWD, all differential ratios $I_{DiffQ}$, $I_{DiffQ'}$ und $I_{Diffmiddle}$ must be taken into account or combined.

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In this context, differential ratio $I_{Diff}$ is yielded as the product of the individual differential ratios. Allowance [must possibly]may need to be made for an effective off-road reduction.

[In the event]If a wheel-speed sensor 9, 10, 11 or 12 is not in working order, [an]the corresponding or comparable (or equivalent) quantity [which describes]describing the speed of the wheel can be calculated for the wheel having the defective wheel-speed sensor using the exemplary method of the present invention. Thus, a shutdown of a complete vehicle-dynamics control system or a complete traction control system [is]should no[ longer]t be necessary. For example, [it is conceivable to make ]an ABS function, i.e., a traction control system which is based solely on braking interventions, [possible]may be provided up to a specific vehicle speed with a defective wheel-speed sensor 9, 10, 11 or 12. The probability of the failure of the complete vehicle [is]should therefore be markedly reduced. This should hold[s] true in particular for off-road vehicles in which external wheel-speed sensors 9, 10, 11, 12 [are]may be subject to particularly high external stress during off-road travel. The shutdown behavior for the ABS case, i.e., the brake-slip control contained in the vehicle-dynamics control, [can]may also be developed more favorably[, as well].

Figure 2 shows a flowchart of the exemplary method according to the present invention. The exemplary method begins in a functional block 30. In the following, it is assumed that the motor vehicle has a front-wheel drive (FWD), and [the intention is to determine an equivalent]a corresponding or comparable quantity describing the speed of wheel 2 must be determined. To that end, in a functional block 31,[ first of all] a variable specific to the wheel plane and describing output speed $V_{output}$ of transmission 5 is first determined.

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Output speed variable $V_{output}$ is determined as a function of transmission output rpm $n_{output}$ according to the following equation:

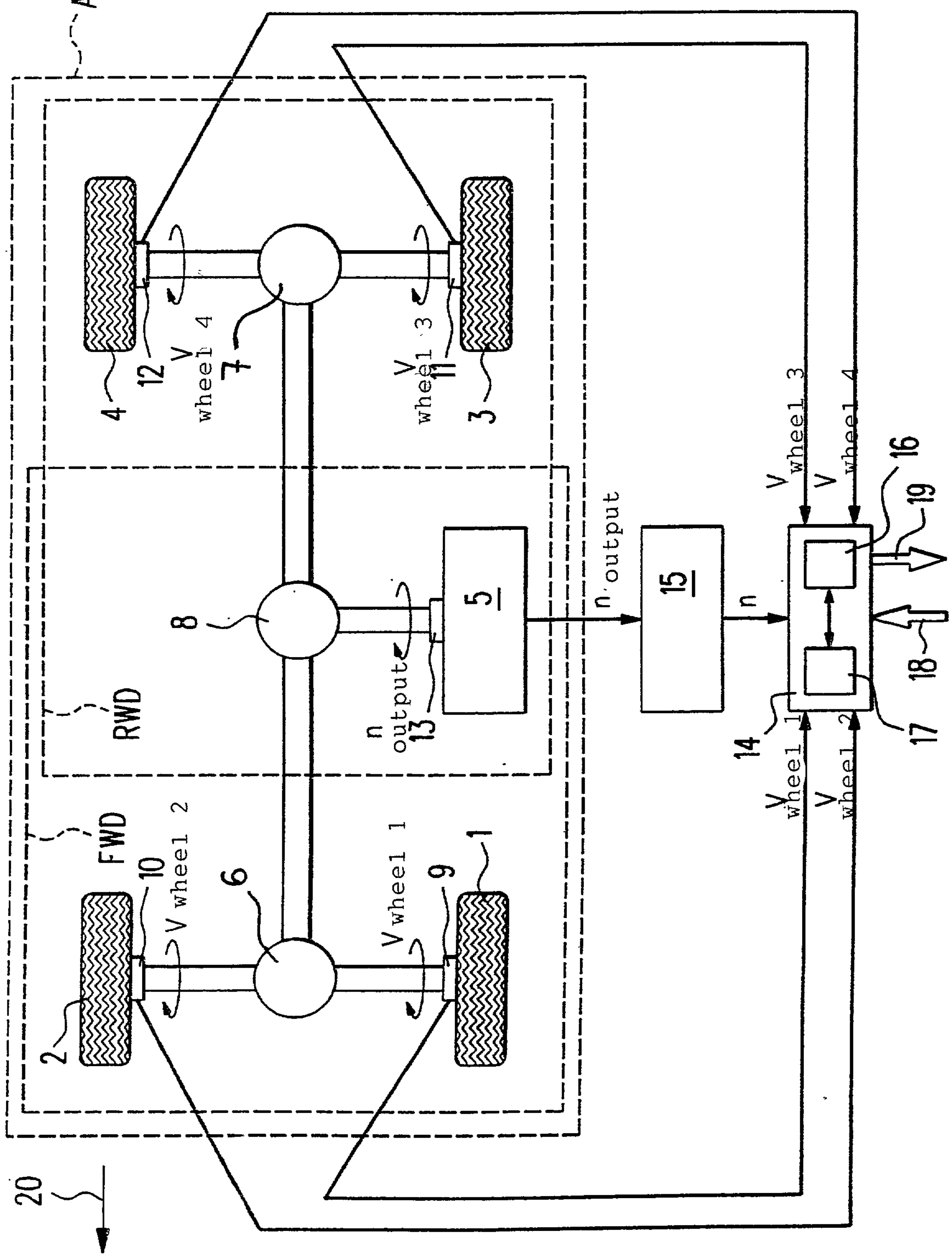
$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output} \ .$$

The corresponding or comparable (or equivalent) quantity describing speed $V_{wheelDef} = V_{wheel2}$ of wheel 2 is subsequently determined in a functional block 32 according to the following equation:

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel} \ .$$

In this context, $V_{wheel}$ is the speed of wheel 1 having speed sensor 9 in working order. In a functional block 33, the exemplary method of the present invention is then brought to an end.

Wheel-speed variable $V_{wheelDef}$, determined [with]using the [aid of the]exemplary method according to the present invention, is compared to wheel speed $V_{wheel2}$[ which was] detected by speed sensor 10 of wheel 2. If the deviations of the two wheel speeds exceed a specifiable threshold value, a malfunction of speed sensor 10 is assumed. [Naturally, w]Wheel-speed variable $V_{wheelDef}$ [utilized]used with the exemplary method of the present invention can also be [utilized]used as a corresponding or comparable (or equivalent) quantity for wheel speed $V_{wheel2}$ of wheel 2 [in the event]if speed sensor 10 is defective.



AWD
FWD
RWD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
V wheel 1
V wheel 2
V wheel 3
V wheel 4
n output
n


Fig. 1

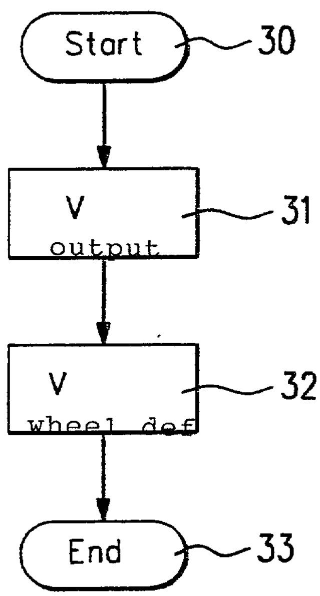



*Fig. 2*

[10191/1961]

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD AND DEVICE FOR DETERMINING A SPEED VARIABLE OF AT LEAST ONE DRIVEN WHEEL OF A MOTOR VEHICLE**, the specification of which was filed as PCT International Application No. **PCT/EP00/12365** on December 8, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:



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**PRIOR FOREIGN APPLICATION(S)**

| Number | Country filed | Day/month/year | Priority Claimed Under 35 USC 119 |
|---|---|---|---|
| 199 59 018.4 | Fed. Rep. of Germany | 8 December 1999 | Yes |

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

Please address all communications regarding this application to:

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**CUSTOMER NO. 26646**

Please direct all telephone calls to Richard L. Mayer at (212) 425-7200.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

1-00

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